AFIT/GLM/LAL/99S-4

COMPARISON OF THE EFFECTS OF EIGHT-HOUR AND TWELVE-HOUR SHIFTS ON AIR FORCE AIRCRAFT MAINTENANCE PRODUCTION LEVELS

THESIS

DAVID P. COLLETTE
CAPTAIN, USAF

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Presented to the Faculty of the Graduate School of Logistics

and Acquisition Management of the Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

David P. Collette, A.S., B.S.

Captain, USAF

September 1999

Acknowledgements

There are many people I would like to thank for assisting me with this thesis project. First and foremost I would like to thank my family for their patience and understanding during the whole education process and the past year of family events. I would like to give a sincere thank you to my classmates, without them to lean on and brainstorm I would not be able to complete this project. I would like to thank Dr. Guy S. Shane for volunteering to work as my advisor, for letting me run my own course, and for giving just enough guidance to keep me on it. Thanks also to Major Michael T. Rehg for his patience and guidance as my reader.

A special thanks goes out to SSgt Erik Gustafson of the Logistics Support Squadron, Dover AFB, Delaware for providing the 1998-1999 period of data and to MSgt John Colleran of the 436th Aircraft Generation Squadron, Dover AFB Delaware for providing the manning data.

Lastly, I would like to thank all the wonderful people, who helped me through the editing process, your efforts helped round out this project.

David P. Collette

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Abstract

This is a follow-on study that examined the effects of converting a large aircraft maintenance squadron from 8-hour shifts to 12-hour shifts. The squadron studied converted its 24-hour maintenance work force from three 8-hour work shifts to two 12-hour work shifts. Data was collected from four different time periods. Three time periods were used for a primary analysis and all four time periods were used for trend analysis. To determine if the 12-hour work shift was effective, workforce productivity was measured during the different work shift periods. Results showed an increase in two productivity measurements, no-change in two productivity measurements, and a decrease in one productivity measurement. It was concluded that 12-hour shifts have a moderate impact on productivity measurements.

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I. Introduction

Background

In a 1991 report, the Office of Technology Assessment estimated that 20 million people, or one of every five workers, in the United States work a non-standard schedule (Office of Technology Assessment 1991). Non-standard is defined as 1500-2300 (swing shift), 2300-0700 (mid-shift), 1800-0600 (mid-shift), etc. For those working the night shifts (mid-shift), the issue of fatigue is quite serious. A recent study estimated that 75 percent of those working at night experience sleepiness every night and approximately 20 percent of these workers actually fall asleep during their work shift (Palmer, et al., 1996:5).

Shiftwork often implies rotating or changing work hours; however, this is not a common characteristic of shiftwork in the aviation maintenance industry. One aspect of shiftwork that is relevant to aviation maintenance is the work that is performed during the midnight to dawn hours, which includes the 2300-0700 and 1800-0600 work periods. Working during nighttime hours can lead to a number of physical and physiological problems compromising a worker's well-being, leading to safety lapses, and reducing productivity levels.

In the aviation maintenance industry, the most common cause of wake-sleep cycle disruption is working at night. Depending on the individual, the physiological and psychological disturbances caused by disrupting the wake-sleep cycle range from moderate to severe. One physiological influence, body temperature, causes interruptions in the wake-sleep cycle, negatively impacting alertness. A decrease in alertness often leads to an increase in error rate. For occupations with a low-tolerance for errors such as piloting, air traffic control, and aircraft maintenance, alertness-related performance decrements can be critical. The decrease in alertness is expected to have a negative impact on productivity levels as the workforce could become less productive and/or more error prone.

Periods of Study

Data has been collected for the past five years on the 436th Aircraft Generation Squadron, Dover AFB, Delaware. One time period was omitted from the study because the squadron was in a transition phase. During this transition, one-half of the workforce was on 8-hour shifts while the other half was on 12-hour shifts. This leaves four years of solid data. In order to add some structure to the research, data has been collected and defined in Table 1.

Purpose of Study

The purpose of this thesis is to build on the work presented in Captain Kelly Scott's 1998 thesis who focused on Periods One through Four. This study adds a fifth period of data collected from an 8-hour shift routine from October 1998 to February

1999. The fifth 8-hour period of data was added because it is significant to look at a time period similar in distance, in terms of time, from the fixed 12-hour shift routine.

Table 1. Data Period Definition

Period	Length	Dates	
One	8-hours	Oct 94 - Feb 95	Included
Two	8/12 -hours	Oct 95 - Feb 96	Omitted
Three	12-hours	Oct 96 - Feb 97	Included
Four	8-hours	Oct 97 - Feb 98	Included
Five	8-hours	Oct 98 - Feb 99	Included

This fifth period accumulates data after the workforce had returned to an 8-hour shift routine and had been on this stable schedule for at least a year. Using this fifth period, we are able to look for differences in the period means, that may or may not be significant, with a stronger research design than Captain Scott was able to capture.

Terms Defined

"Shiftwork research is a multi-faceted field. Many situational factors exist which can lead one to various conclusions about the affects of shiftwork. On the surface, these conclusions may even seem to be contradictory. However, close examination of the many factors involved will result in focused conclusions that are relevant to the particular shiftwork routine under study" (Scott, 1998:2). For this reason, definition of the

following terms as they apply to this study is required. Scott defines the following terms as:

> *Shiftwork*: The schedule implemented by the organization under study – two 12-hour shifts provide 24-hour coverage with a 2-day on, 3-day off, 3-day on, 2-day off schedule.
>
> *8-hour shifts*: Three work shifts per 24-hour day, each lasting about eight hours – a traditional day shift, swing shift, and mid-shift routine.
>
> > *Day shift*: An 8-hour work shift that begins at 0700 and ends at 1500 the same day.
> >
> > *Swing shift*: An 8-hour work shift that begins at 1500 and ends at 2300 the same day.
> >
> > *Mid-shift*: An 8-hour work shift that begins at 2300 and ends at 0700 the following calendar day.
>
> *12-hour shifts*: Two work shifts per 24-hour day, each lasting about 12 hours – a day shift and a night shift.
>
> > *Day shift*: A 12 hour work shift that begins at 0700 and ends at 1900 hours the same day
> >
> > *Night shift*: A 12-hour work shift that begins at 1900 and ends at 0700 the following calendar day.
>
> *Rotating shifts*: Any shiftwork schedule that routinely requires workers to change either their work shift or their scheduled duty days.
>
> *Fixed shifts*: Non-rotating shifts. A stable consistent work schedule with a repeating day and shift pattern.
>
> *Compressed shifts*: Working longer shifts each day, but fewer days each week (Scott 1998:3).

Outcomes of Interest

The outcome of interest in this study is organizational performance, specifically mission capable rate. Organizational performance refers to measures of productivity or mission success. A major goal of an aircraft maintenance unit is to generate reliable, mission-capable aircraft in sufficient numbers to meet the operational schedule. Organizational performance will be examined using mission-capable rate, direct labor-

hours per flying hour, awaiting maintenance discrepancies, home station reliability, and 12-hour fix rate. These indicators are described in AMC pamphlet 21-102, Unit Health of the Force and Maintenance Analysis Guide, which defines the methods and formulae used by Air Mobility Command analysts. Typical uses of data from Air Force reporting systems of this type include Health of Forces reports and statistical analyses for congressional committees, the Office of Management and Budget, and the Department of Defense (AFI 21-103, 1997:1).

Problem Statement

Dwindling budgets and manpower levels, aging aircraft, and increasing operations tempo all place additional workloads on aircraft maintainers. Shiftwork is one way the Air Force attempts to meet these challenges because not all work is expected to be done during daylight hours (Scott, 1998:5). It is the author's opinion that by increasing manpower availability, shiftwork generally increases the mission capable rate over short periods, but may have mixed effects on performance over longer periods resulting in a higher degree of operational readiness. Air Force leaders should thus weigh the pros and cons of shiftwork to make the best-informed decision needed to meet operational requirements (Scott, 1998:5).

In the mid 1990's the 436th Aircraft Generation Squadron utilized a long period of 12-hour shifts to compensate for a reduction in manning and an increase in the flying schedule. The final phase of the research of this squadron evaluates two periods of 8-hour shifts that are equidistant, in terms of time, from the 12-hour period: the first 8-hour (Period One) ends about one year prior to the squadron implementing the 12-hour shift

routine, and this last period of research (Period Five) starts about one year after the squadron terminated the 12-hour shift routine.

Research Objectives

My thesis examined the differences that exist between the Mission Capable (MC) Rate data presented in Periods One, Three, Four and Five. This change in MC Rate could be as a result of implementing 12-hour shifts and re-implementing 8-hour shifts. Specifically, my thesis will attempt to answer the following research questions:

1. Does the implementation of a fixed 12-hour shift routine (period 3) produce Mission Capable Rate results that are higher than the 8-hour shift routines (periods 1, 4, and 5) and then degrade after suspected onset of worker fatigue?
2. Does the average Mission Capable Rate of the 12-hour shift routine (period 3) exceed the average mission capable rates of the 8-hour shift routines (periods 1,4, and 5).

Returning to the 5-day, 8-hour shift routine, especially after having made the adjustments to 12-hour shifts, may be accompanied by decreased organizational performance due to a lower level of worker satisfaction (Budnick, et al., 1994:1296). Organizational performance may also decrease when the off-duty hours are reduced to Saturday and Sunday after the general practice of having three-days off in a row is eliminated.

Prior AFIT Research

Prior Air Force Institute of Technology (AFIT) research on this issue is discussed in a 1997 thesis by Captain Dan Overland and in a 1998 thesis by Captain Kelly Scott. Captain Overland examines period one and three, while Captain Scott examines periods one, three, and four. Both individuals examine the 436th Aircraft Generation Squadron (AGS) specifically effects of an 8-hour duty day vs. a 12-hour duty day on performance indicators and health and safety.

"The 436th AGS completely converted to a 12-hour duty day in July of 1996" (Overland, 1997:9). Additionally, Scott states "the two 12-hour shifts provided 24-hour coverage with a 2-day on, 3-day off, 3-day on, 2-day off schedule. Over a 6-month period, a worker would be on duty an average of 3.54 days (42.46 hours) per 7-day period. The additional hours worked have the net effect of adding the equivalent of 47 workers to the unit over a 6-month period" (1998:2). Fourteen months later, in September of 1997, the squadron converted back to an 8-hour duty day. This thesis includes data similar to that used by Scott, and adds a third comparison period of 8-hour duty days (identified in this study as period five) to examine the effects of shiftwork on the 436th AGS.

II. Literature Review

Shiftwork Research

The use of 12 hour or extended shifts may have a wide range of organizational and individual consequences (Overland, 1997:3). Research on shiftwork falls into two categories: the effects of shiftwork on organizational goals, i.e. productivity and efficiency, and the effects on the individual, i.e. social issues, and heath and well being. (Allusia, 1982:176). The military has primarily been concerned with the effects of extended work periods on aircrew and soldier effectiveness (Haslam, 1980:555; Palmer, et al, 1996:2; Scott, 1998:3). As such, there is not a lot of military research on the effects of shiftwork on organizational goals, nor is there a lot of research within the civilian aviation maintenance community on shiftwork and the companies' goals.

Shiftwork's Effect on Productivity

The conversion from 8- to 12-hour shifts is expected to lead to an increase in productivity per worker (Pierce and Dunham, 1992:1086). Of course the corollary, a conversion from 12- to 8-hour shifts is expected to lead to a decrease in productivity per worker, exists. Although overall efficiency may increase, research indicates individual workers' efficiency decreases as the workday progresses (Overland, 1997:3). In fact, worker performance has been found to be significantly degraded when working a 12-hour shift as compared to an 8-hour shift (Rosa, 1991:115). As a result, work which requires complex cognitive skills, such as flying and repairing high tech equipment, should not be considered for longer shifts (Duchon and Smith, 1993:38; Nicholson and Stone,

1982:33). On the other hand, work scenarios, which require limited reasoning and a fairly low level of physical activity, may be suited for longer shifts (Overland, 1997:3).

Shiftwork and Fatigue

Workers on extended shifts often complain of symptoms of fatigue and attention deficit (Rosa, et. al., 1989:26-30). The authors also support the theory that longer shifts cause greater fatigue. Although workers report greater feelings of fatigue associated with longer shift, they also prefer longer shifts because it condenses their work week, giving them more time off (Budnick, et. al., 1994:1295). These effects of fatigue can be reduced by a few minutes of vigorous physical activity (Maddox, 1999:4-7-6). Extended shifts have been shown to have significant effects on workers. Increased occurrences of health problems, a factor which can contribute to poor performance and increased absenteeism, are directly related to longer shifts and compressed work schedules (Overland, 1997:4). These factors all impact productivity. If a worker is not present to perform or performs poorly, then long-term productivity factors should decrease. Williamson et al theorize the increase in absenteeism is associated with longer work shifts and condensed work schedules possibly resulting from a change in mental state, such as fatigue, sleep loss and or disruption of circadian rhythms (1994:296).

The circadian rhythm disruption is a rising concern as the Bureau of Census for the Bureau of Labor Statistics estimated in 1993 that approximately one in five Americans is a shift worker. Shift workers include workers who work a night shift, rotate from one shift to another, or work schedules different that a typical 8-hour day (Campbell, 1998:3). It is important to mention that a person's physical fitness can predict

how well a person adapts to shift work (Ferrer et. al., 1995:572). The authors found that individuals who are physically fit have higher circadian rhythm amplitudes than unfit individuals, and those with high circadian rhythm amplitudes are more tolerant to shift work. The circadian rhythm is the body's internal clock, which has a longer than 24-hour intrinsic period, but is synchronized to the 24-hour day by cues from our external environment (zeitgebers), e.g., light, temperature and routine mealtimes (Graeber, 1988:310-311). The body's internal clock also regulates certain physiological functions such as body temperature and hormonal release. The internal clock can be reset, at a rate of about 1-hour per day. When workers are forced to alter their sleep/wake cycle abruptly to correspond to a new work shift, there is usually a mismatch between the body's internal clock and the new sleep/wake periods (Gordon, 1986:1226). It may take several days to overcome this degradation of performance. Monk suggests that the adjustment is never completely made during shiftwork routines (1989:12).

Night shift workers average two to three hours less sleep per day than day shift workers (La Dou, 1982:525). Obtaining even one hour less sleep than required can affect waking levels of sleepiness (Rosekind, 1994:328). Another study estimates that 75% of those working at night experience sleepiness every night. Twenty percent of those workers actually fall asleep on their work shift (Akerstedt, 1992:4). All of these factors combine to reduce productivity towards the end of a dayshift and on an entire night shift.

Shiftwork and Performance

Many organizations attempt to increase performance by changing from three 8-hour shifts to two 12-hour shifts (Pierce and Dunham, 1992:1086). While it is commonly

perceived that 12-hour shifts are more productive, care must be taken not to confuse performance with productivity. Productivity is an essential factor in determining performance (Scott, 1998:8).

Researchers have found performance is reduced at night. In a 12-hour shift operation, theoretically half of the workload is done at night. In an aircraft maintenance environment, the night shift does much of the workload – especially corrective maintenance (Scott, 1998:8). Studies have shown that shiftwork is linked to decrements in performance, even after the shift routine was in place for more than three years (Rosa, 1991:115). Alluisi and Morgan cite several studies that conclude night shift performance is inferior to that of day shift (1982:176-177). Lewis and Swaim evaluated performance measures for 8- and 12-hour shifts, and found no significant increase in performance between the two shift routines (1986:886-887). Baker and Morisseau evaluated performance of nuclear power plant workers on 12-hour shifts and found that performance of cognitive tasks is impaired on 12-hour shifts. Additionally, they observed an increase in fatigue and drowsiness as the 12-hour shift progressed resulting in a reduced learning curve and reduced manual coordination (Baker and Morisseau, 1992:117). When these individual personal performance factors are summed across an entire group, such as aircraft maintainers, we should expect organizational performance to also degrade as the 12-hour shift progresses.

A comprehensive analysis of the factors that influence the relationship between shiftwork and performance is key to understanding the effects of shiftwork (Scott, 1998:9). Performance is believed to depend upon three factors: (1) task demand, (2) type

of shiftwork system, and (3) individual differences between shift workers and their ability to adjust to shiftwork (Folkard and Monk, 1979:490).

The type of shift system implemented also plays an important role in performance. For example, a rotating shift tends to be more disruptive to workers than a fixed shift (Scott, 1998:9). Workers on a rotating shift do not have time to adapt to their work hours. Compared to rotating shifts, fixed shifts have been linked to higher performance in manufacturing (Liou and Wang, 1991:64). Maddox notes that it is a common practice in the civilian and military aviation maintenance communities for workers to stay on the same shift for a number of weeks or months (Maddox, 1999).

Additionally, individual differences in circadian rhythm, age, gender, physical fitness, and flexibility in sleeping habits, relate to performance (Harma, 1993:104). Even if these factors are controlled, all humans still possess similar performance limitations (Scott, 1998:10). These limitations help explain why people make more errors during night shifts, particularly on complex tasks (Miller and Swain, 1987:224).

Decreased organizational performance is anticipated during long periods of 12-hour shifts because most of the workload is accomplished at night, the work itself can be complex, and some military maintenance squadrons utilize a variable shift schedule.

Outcome Variables Defined

This section defines the variables that are used to help describe and define this study. These are the variables of interest.

Logistics Readiness Indicators. Accurate performance measures depend on the mission involved and the perspective from which management interest is generated

(Scott, 1998:16). Because of the interdependency in the work performed, complex measures of performance may be required to accurately measure organizational performance (Prichard et al., 1989:339). These interdependencies also explain in part why there tends to be little agreement on the definition of organizational performance measures (Scott, 1998:16). The objective in this study is to measure the effects of 12-hour shifts as closely as possible, while simultaneously avoiding outcome variables that may be influenced by confounding factors for which we cannot control (Scott, 1998:16). Therefore, five Logistics Readiness Indicators have been selected as accurate measures of productivity and will be used to determine the effectiveness of 12-hour shifts. They are:

Mission Capable Rate. The Mission Capable Rate (MC Rate) variable is the outcome of interest and the focus of this study. This indicates the number of hours that an aircraft was either Fully or Partially Mission Capable (FMC or PMC) divided by the total number of hours the aircraft was at the using organization. The MC rate is often reported to higher headquarters as an indicator of the health of the fleet. For this indicator, the closer to 100 percent, the better. Inefficient performance has a negative effect on this indicator because it reduces the number of hours the aircraft are either FMC or PMC (Scott, 1998:16). The short-term effects of 12-hour shifts may include higher performance rates due to the increased personnel resources (Monk, et al., 1996:18). However, as Klein notes, with the passage of time, performance rates are expected to decline as fatigue and stress erode performance measurements (1988:767).

In order to address the first research objective, does the implementation of a fixed 12-hour shift routine (period 3) produce Mission Capable Rate results that are higher that the 8-hour shift routines, hypothesis number one is developed.

H_0: 12-Hour shifts will not result in an increase in MC Rate.

H_a: 12-Hour shifts will result in an increase in MC Rate.

Hypothesis number one will be determined by statistical analysis.

In order to address the second research objective, does the average Mission Capable Rate of the 12-Hour shift routine (period 3) exceed the average mission capable rates of the 8-hour shift routines (periods 1, 4, and 5), hypothesis number two is developed

H_0: 12-Hour shifts do not result in MC Rates that are higher than the 8-Hour shift periods.

H_a: 12-Hour shifts do result in MC Rates that are higher than the 8-Hour shift periods.

Hypothesis number two will be determined by quantitative analysis.

Direct Labor-Hours per Flying Hour. This variable reveals the number of direct labor hours it takes to produce a flying hour. Direct labor hours are hours expended in support of repair operations and include tasks that require a higher cognitive level of work such as fault isolation and operational checkouts (Scott, 1998:17). Shift work is expected to reduce the number of direct labor hours per flying hour, mainly due to reduced shift turnover (Lewis and Swaim, 1986:88). This makes sense as 12-hour shifts result in two turnovers per day whereas 8-hour shifts create three per day. It is anticipated that 12-hour shifts will reduce this variable.

Awaiting Maintenance Discrepancies. The Awaiting Maintenance (AWM) Discrepancies variable is the average number of non-grounding write-ups per aircraft that have been delayed from work. This happens when the owning maintenance unit needs

more time and/or personnel resources to work on the write-up. Parts that are needed to support the maintenance action are already on-hand. According to Scott, the increased manpower availability of 12-hour shifts is expected to reduce the number of AWM discrepancies (1998:17).

Home Station Reliability. This variable measures how often the aircraft is ready on-time divided by the number of times the aircraft was scheduled to fly. Aircraft available early is not important here – either the aircraft is ready or it is not. This measurement is important because it is a production-type (sortie-generation) outcome (Scott, 1998:18). 12-hour shifts are expected to increase Home Station Reliability, because on average, more personnel are available to prepare the aircraft for flight.

Twelve Hour Fix Rate. This variable measures the owning organizations ability to return an aircraft to MC status after the aircraft returns from flight in a non-mission capable (NMC) status. More specifically it is the percent of aircraft returning from a mission in NMC status that are returned to MC status with-in 12 hours of landing (Scott, 1998:18). A high fix rate indicates that a unit can effectively and efficiently repair an aircraft. Some maintenance tasks require higher levels of cognitive work than others and the effects of shiftwork may have a negative effect on this variable. According to Scott, the 12-hour fix rate is expected to decline during 12-hour shifts as increased fatigue and stress lead to less efficient fault isolation and/or repair actions (1998:18).

Workload, Manpower, and Experience Levels

The aforementioned outcome variables are influenced by other factors. However, the objective of this research is to measure the effects of 12-hour shifts accurately and

completely. The three variables of workload, manpower and experience levels all effect the outcome variables. As such, precise and completely unambiguous measurement is unlikely (Cooper and Emory, 1995:147). Therefore, it is necessary to allow for the effects of various factors. The methods used to control for these associated factors are discussed in Chapter III.

III. Method

Data Sources

Concomitant Variables. Concomitant variables represent independent variables that may have an influence in the outcome variables. Controlling for these covariates when comparing the period means is necessary to account for their influence on the dependent and independent variables (Kachigan, 1986:331). In effect, this method tests an alternative explanation for the relationships among the variables of interest (Scott, 1998:21). In this study, several concomitant variables were tested to determine whether they influence the 12-Hour shift impact on the Mission Capable Rate. They are:

Sorties. This is a measure of squadron workload; it is the number of flights launched monthly from the home station. Sortie generation is the squadron's primary indicator of maintenance production (output). Sorties directly affect the maintenance requirements of aircraft systems and represent measures of workload (Scott, 1998:21). The Analysis section within the Logistics Support Squadron (LSS) collected this data.

Hours Flown. This is the sum of all flying hours during the monthly period and represents a measure of workload. Hours flown directly impacts equipment serviceability (Scott, 1998:21). Requirements for many maintenance tasks are based on this indicator – especially engine work, structural inspections, and other critical maintenance actions. Increased flying time generally leads to an increase in maintenance requirements. The number of hours flown provides a measure of workload which differs from the number of sorties. Sortie duration could be long or short. Hours flown can vary depending on the

destination, weather, cargo load, and mission profile. The Analysis section within the LSS collected this data.

Direct Labor Hours. This variable includes only those hours spent in direct support of the weapon system such as repair and servicing time. Indirect labor activities, such as training and administrative time are not included in this variable. This data is a measure of effort expended by the workforce in direct support of the workload (Scott, 1998:22). The Analysis section within the LSS collected this data.

Work Force Skill Level. This variable represents both the manning level and experience of the work force (Scott, 1998:22). Three-level workers are in upgrade training and are usually supervised by five- and/or seven-level workers. Five-level workers usually supervise three-level workers, and also perform some unsupervised maintenance. Seven level workers perform some of the more complex maintenance tasks, may perform unsupervised maintenance, and inspect some of the tasks performed by three- and five-level workers. Occasionally, seven-level workers supervise three- and/or five-level workers. Five- and seven-level workers make up the bulk of the "fully-qualified" work force and account for most of the squadron's productive maintenance (Scott, 1998:22). This variable was computed from the skill level data provided by the squadron mobility and manning office within the 436th Aircraft Generation Squadron (AGS). It is the sum of five- and seven-level workers, divided by the sum of three, five, and seven-level workers (Scott,1998:22).

Manpower. This variable indicates the manning level of the squadron. It is a measure of the assigned personnel and represents, in terms of personnel strength, the squadron's personnel resources assigned to accomplish the workload. In this study, it is

the monthly average of the three-, five- and seven-level workers (Scott, 1998:22). The Manning office within the 436th AGS collected this data.

Logistics Readiness Indicators

There are many Logistics Readiness Indicators used in this study. As discussed in Chapter Two, they are: Mission Capable Rate, Direct Labor Hours per Flying Hour, Average Awaiting Maintenance Discrepancies, Home Station Reliability, and 12- Hour Fixed Rate. The Analysis section of the LSS collects data from each of these indicators. These indicators are described in the Air Mobility Command Pamphlet 21-102, "Unit Health of the Force and Maintenance Analysis Guide." The Air Force reports this type of data for Health-of-Forces reports and statistical analysis for the Department of Defense, Congress, and the Office of Management and Budget (AFI 21-103, 1997:8).

Observation Periods

Data from the four-time periods will be compared to measure possible changes in organizational performance. Each time period will be five months long, and include approximately 150 days of performance data. The periods were chosen to reflect as closely as possible, day-to-day unit operations under one of three conditions: a normal fixed 8-hour shift before any schedule changes, a fixed 12-hour shift schedule and two fixed 8-hour shift schedules after the 12-hour operation ended (Scott, 1998:24).

The four-time periods all began on the first day of October and end the last day of February. Beginning at the start of a fiscal year increases the likelihood of a similar flying schedule throughout this study (Scott, 1998:25). The addition or deletion of sorties

for fiscal reasons is less likely in this period than in August or September as these two months typically have greater flying schedule fluctuation than other times of the year. Selection of homogeneous time periods avoid seasonal effects in the data that may be caused by different weather conditions or changes in the work force caused by the reassignment of military personnel (Campbell and Stanley, 1963:39). Reassignments occur primarily between May and August each year. For example, aircraft maintenance in winter conditions is quite different from aircraft maintenance under summer conditions (Scott, 1998:25). Lastly, using the same months in the same time periods ensures the length of daylight hours remains as constant as possible. This reduces differences in circadian synchronization cycle between work periods, which could influence the data.

Period One, the pre-treatment period, includes October, 1994 through February, 1995. During this time, squadron maintenance personnel worked a fixed three-shift, five-day, 8-hour shift routine. During this period, no plans were in existence to change to 12-hour shifts. Thus, this period represents a fairly stable operational period, suitable for use as a baseline period against which two subsequent periods can be compared (Scott, 1998: 25).

Period Two, is represented by the October, 1995 through February, 1996 time window. According to Scott, the squadron incrementally phased in the 12 hour shift routine, first moving one-half of the workers to 12-hour shift in February, 1996 (1998:26). Therefore, the October, 1995 to February, 1996 period can not be used for this analysis, because of the initial implementation of 12-hour shifts occurred in this period. Additionally, as a 12-hour shift implementation had been discussed for some time, uncertainty and apprehension in the work force might have had a confounding

effect on performance. The remainder of the work force moved to 12-hour shifts in July, 1996. The difference in shift routine confuses the data, rendering it unusable. Therefore, data from this period was not collected nor used for analysis.

Period Three, chosen to represent the 12-hour shift treatment time, runs from October, 1996 through February, 1997. During this period, nearly all maintenance technicians were working 12-hour shifts. They had been on 12-hour shifts for at least four months, an adequate period to adapt to a 12-hour shift schedule (Monk, 1989:553). The only exceptions to the 12-hour shift routine are a small group of supervisors who were on 8-hour shifts.

Period Four represents a return to the same 8-hour shift routine as Period One. This post-treatment period begins in October, 1997 and ends in February, 1998. The squadron was on 12-hour shifts until September, 1997. This particular period will be used for trend analysis and not for primary use, as it is not equidistant from the 12-hour period when compared to pre-treatment period.

Period Five represents the same 8-hour shift routine as Period One and Four. This post-treatment period begins in October, 1998 and ends in February, 1999. Period Five and Period One are the same distance, in terms of time, from Period Three. The addition of Period Five to the previously accumulated data will strengthen the overall results of this study. Cooper and Emory concur with this idea and state "Ideally an examination of the changes experienced after returning to the 8-hour shift routine would come from a time period equidistant from the treatment period" (Period Three) (1995:358). This will give a more accurate insight as to whether or not the outcome variable returned to the same level as observed in the pre-treatment period (Scott, 1998:26).

Data Analysis

After the data was gathered and organized, statistical tests and specific methodologies were examined to determine any difference in the MC Rate before, during, or after the 12-hour shift period.

Test for Normality. Normal Q-Q plots will be produced for all the containment and outcome variables. The residuals should plot in a linear fashion. There should be no reason to believe the data distribution would lead to an incorrect conclusion.

Bartlett's Test of Homogeneity of Variances. The Bartlett's test checks to see whether or not the variances are equal between-period means. When sample sizes are equal, as in this study, the F test is only slightly affected by unequal variances (Neter et al., 1990:624). If the F Test is significant and the variance is significant, then the variable is a good candidate for further inclusion in the model.

Analysis of Variance/Covariance. To compare the three period means, an Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA) are used. The overall F test used in these methods is robust against departures from normality in the data, and ANOVA methods produce good results when departures from normality are not extreme (Neter et al., 1990:623 and Scott, 1998:28).

Tukey Test for Multiple Comparisons. ANOVA and ANCOVA simply indicate whether or not a difference between the period means exists (Scott, 1998:28). The Tukey test will identify which period means differ from each other and was developed specifically for pairwise comparisons when the sample sizes are equal. This test is a conservative one and was used to determine which period means differ (McClave et. al., 1994:822).

Trend Analysis. If the change in Logistics Readiness Indicators is statistically significant, then a qualitative trend analysis will be performed. The trend will be analyzed over the four data periods to draw conclusions based on the direction and amount of movement in the line of regression. To reduce internal threats to validity, the time periods used for comparison will be identical. Trend analysis is a far more flexible method of drawing conclusions and allows for creativity on the part of management when it comes to making decisions based on the data contained within the study (Reynolds, 1999).

Data Limitations

This study attempts to minimize threats to internal validity. In this particular study, as with most military studies, it is difficult to control for history, maturation, and experiment mortality (Shane, 1998). This is due in large part to the general nature of the military establishment. For example, major unit deployments and multiple transfers of aircraft or personnel serve to threaten this study's results. As such, finding a stable period of time is a very difficult thing to do because many things in the internal environment are potential contaminants affecting variable of interest. Many times these changes are not at the same rate or direction.

This study's generalizability is limited to similar aircraft units organized in the AGS structure and maintaining heavy airlift aircraft. Within this framework, the results presented should serve as a strong indicator of the effects of 12-hour shifts. Senior management, however, should use caution when interpreting these results as they will vary from aircraft design to aircraft design and could vary based on geographic location

of the Air Force bases selected. Additionally, this study is accomplished during the fall and winter periods in the state of Delaware. This particular time period has longer nighttime hours and lower average temperatures than any other period of the year. The longer nighttime hours and cold temperatures may skew the data as the workforce is anticipated to perform work at a slower pace during this period of the year. However, this be somewhat offset by limiting the contaminating effects of multiple transfers, reassignments, or deployments which tend to occur less frequently during the winter months.

IV. Results and Analysis

Comparisons/Analysis Model

To determine if there was a significant difference between their period means, an ANOVA was performed on each of the concomitant variables. The concomitant variables that do not significantly differ between periods add little or no explanatory information to the experiment (Scott, 1998:29). Those variables that do not significantly differ were not used in the final analysis. Of the five concomitant variables tested, mean Sorties and mean Hours Flown were not found to be statistically different. However, both mean Work Force Skill Level, mean Manpower were significantly different ($p<0.001$) and mean Direct Labor Hours is significantly different ($p<0.003$). Thus, these three variables are candidates for further analysis. A Bartlett's test indicated equal variance for Work Force Skill Level ($p<0.002$) and unequal variances for Manpower ($p<0.29$) and Direct Labor Hours ($p<0.16$). As a result, only Work Force Skill Level is considered a reliable concomitant variable because it has statistically different means and has equal variance. Therefore, the final model selected to examine the outcome was a one-way ANCOVA design with the Work Force Skill Level covariate.

Concomitant Variables

Table 2 shows the ANOVA results for comparing the difference between period means for each of the concomitant variables (Scott: 1998:30). Two of the five variables tested were found to have different mean values between periods. Manpower shows a substantial decline between all three periods. Workforce Skill Level is highest in Period

Three, with approximately 75 percent of the work force consisting of five- or seven-level workers. Direct Labor Hours are lower in Period Five than in Periods One and Three; however, this could be attributed to the decreasing trend in the Sortie rate as we would expect the workforce to expend proportionately less hours as the Sortie rate drops.

Table 2. Comparison of Concomitant Variables

	Monthly Means				
Concomitant Variable	Period 1 8-Hr Shift	Period 3 12-Hr Shift	Period 5 8 Hr Shift	Difference Between Means	Periods Different
Manning Level	935	709	683	p < .001*	all
Work Force Skill Level	65%	75%	64%	p < .001*	3 from 1,5
Direct Labor Hours	42,366	41,992	30,955	p < .003*	5 from 1,3
Sorties	522	419	371	non-significant	na
Hours Flown	2,005	1,797	1,717	non-significant	na

Note: *Indicates differences are statistically significant, p<.05

Manpower. There is strong evidence that the manning level (manpower) declined (p<.00) steadily over all three periods. This decline could be attributed to force reductions brought about by downsizing throughout the Air Force (Scott, 1998:31). This reduced manpower level could also account for part of the reduction in MC Rate.

Work Force Skill Level. There is strong evidence that the work force skill level was significantly different during Period Three from Periods One and Five (p,<.00). This condition is reasonably expected to have an influence on the Logistics Readiness Indicators (Folkhard and Monk, 1979; Scott, 1998:32). Controlling for the change in workforce skill level removes the effects of the change in worker experience and the number of personnel available to accomplish the workload yielding a clearer picture of the effects of 12-hour shifts (Kachigan, 1986:331).

Direct Labor Hours. The average number of direct labor hours expended per month was significantly lower in Period Five than in Periods One and Three (p,<.00). At first glance Period Five appears to be abnormally low; however, the decreasing trend follows a similar decreasing trend in Sorties. It makes sense that as the Sortie rate declines the workforce should be expending fewer labor hours throughout the month.

Sorties and Hours Flown. The average number of sorties and hours flown per month was not significantly different between the three observation periods. The trend observed by dividing Sorties into Hours Flown reveals that the volume of missions is getting smaller; however, mission length is growing. In fact the mission length in Period Five is an average of 20 percent longer than in Period One. While this growth in mission length is interesting, it is not statistically significant. Therefore, it is safe to conclude that the workload, in terms of sortie generation, remained relatively constant throughout all three-observation periods.

Logistics Readiness Indicators

Table 3 shows the ANCOVA results for comparing the differences between period means on each of the Logistics Readiness Indicators. The ANCOVA controlled for the effect of Work Force Skill Level in these indicators (Scott, 1998:32). The mean MC Rates is significantly lower in Period Five than in Periods One and Three. A 1.3 percent increase was observed when the workforce went into 12-hour shifts, followed by a 14 percent decrease when the workforce came out of the 12-hour shift period. The average number of labor hours used to get one flying hour increased by 1.46 hours during the 12-hour shift period, followed by a 5.13 decrease in Period 5. The Home Station Reliability increased during the 12-hour shift period by 13 percent, followed by a 12 percent decrease in Period 5.

Table 3. Comparison of Logistics Readiness Indicators

	Monthly Means				
Logistics Indicator**	Period 1 8-Hr Shift	Period 3 12-Hr Shift	Period 5 8 Hr Shift	Difference Between Means	Periods Different
MC Rate	69.14	70.44	61.6	p < .03*	5 from 1,3
LaborHrperFlyHr	22.37	23.83	18.7	non-significant	none
AWM	21.02	11.74	13.8	p < .03*	1 from 3,5
HS Reliability	79.48	89.52	80.0	p < .01*	3 from 1,5
12-Hour Fix Rate	56.66	53.58	65.4	non-significant	none

Notes: * Indicates differences are statistically significant, p<.05
** Effects of Work Force Skill Level controlled for

There were no other significant differences between the other Logistics Readiness Indicator means.

Mission Capable Rate. The MC Rate was expected to decline as worker fatigue increases the longer they are on 12-hour shifts (Folkard and Monk, 1979:485). The statistical analysis fails to support Folkard and Monk's expected outcome as an improvement in the MC Rate was observed during the 12-hour shift period. The MC Rate was 1.3 percent higher in Period Three than in Period One, and this is consistent with Rosa, et al., (1989:23), Williamson, et al., (1994:292), and Scott (1998:33) who report increases in performance during 12-hour shifts. While the differences between Period Three and Period One are not statistically significant, the trend is important to note. This improvement can most likely be attributed to increased personnel resources associated with 12-hour shifts (Folkard and Monk, 1979:487; Rosa, 1991:109; Scott 1998:34). This finding is further supported by an 8.85 percent decline, during Period Five, for the MC Rate after the squadron returned to 8-hour shifts. The difference between Period Three and Period Five is statistically significant, therefore it is safe to conclude that the 12-hour shift period had a statistically positive impact on this measure of productivity.

Direct Labor Hours per Flying Hour. During 12-hour shifts, there are 50 percent fewer shift turnovers resulting in better communication between work shifts. Lewis and Swaim report that workers communicate back and forth with each other during two 12-hour shift periods resulting in better continuity and more efficient work when compared to three 8-hour shift periods (1986:888). This variable was expected to

decrease during 12-hour shifts, mainly due to more efficient operations (Scott, 1998:34). This hypothesis was not supported by the data. In fact, the mean actually increased by 1.46 labor hours per flying hour for the 12-hour shift period followed by a decrease of 5.13 labor hours in the final 8-hour shift period. Even though these differences are not statistically significant, it is important to note the unexpected trend in the data. This variable is computed dividing Direct Labor Hours by Hours Flown, it appears that the workforce did more maintenance related activities during the 12-hour shift period. Therefore, it is safe to conclude that the 12-hour shift period had a negative impact on this measure of productivity but the impact is not statistically significant.

Awaiting Maintenance Discrepancies. The average number of AWM discrepancies was expected to decrease during 12-hour shifts (Scott, 1998:35). This hypothesis was supported by the collected data. The 12-hour shift period resulted in a 79 percent decrease in the number of AWM discrepancies. The difference between Period Three and Period One is statistically significant. The mean comparison also indicates that Period Three and Five are not significantly different. Excellent management of the resources required to keep this indicator low could explain why the data collected for Period Five is not different from Period Three. Therefore, it is safe to conclude that the 12-hour shift period had a statistically positive impact on this measure of productivity.

Home Station Reliability. Home Station Reliability measures the ability of the work force to prepare the aircraft in a timely manner to meet the flying schedule (Scott, 1998:35). The average Home Station Reliability was expected to improve during the 12-hour shift period, and this is supported by the data. After the statistical analysis is accomplished, and the effect of Work Force Skill Level removed, the difference between

Period One and Three is statistically significant. Additionally, the difference between Period Three and Five is also statistically significant. Therefore, it is safe to conclude that the 12-hour shift period had a statistically positive impact on this measure of productivity. Also, it is interesting to note that this variable is the only one for which a significant difference was found between Period Three (12-hour shift period) and Periods One and Five (8-hour shift periods). It seems that the 12-hour shift period had the most direct impact on this variable. Therefore, management could interpret these findings, as 12-hour shifts are an effective way to improve Home Station Reliability.

Twelve Hour Fix Rate. This indicator measures the squadron's ability to return the aircraft to mission capable status within 12 hours of the aircraft landing in a non-mission capable status (Scott, 1998:36). Due to the increased task complexity associated with this type of maintenance, 12-hour shifts were expected to have a detrimental effect on this indicator (Folkard and Monk, 1979:489; Scott, 1998:36). The trend in the data supports this idea, however, there is no statistical significance in any periods after the effect of Work Force Skill Level is removed. Therefore, it is safe to conclude that the 12-hour shift period had some negative impact on the 12-hour shift rate, but this impact is not statistically supported.

Trend Analysis

Mission Capable Rate. Mission Capable Rate was plotted for trend analysis. At this point in the study, all four periods of usable data are plotted and displayed in Figure 1. As stated earlier, data for Period Two is not used, however Period Two is represented by the gap. The visual inspection method illustrates a downward sloping trend for the

MC Rate. It is interesting to note that the MC rate for the first two months of 12-hour shifts (data points 11 and 12) are higher than any other measurement, and that the rate degraded through data points 13, 14 and 15.

As stated earlier, there is a statistical difference between Period Five and Periods One and Three. However, Period Four is not statistically different from any other observation periods. Therefore, it is safe to conclude that the trend in the MC Rate is downward sloping. Management would prefer to see a stable or upward sloping trend for this indicator as this would show that the MC Rate is stabilized or improving.

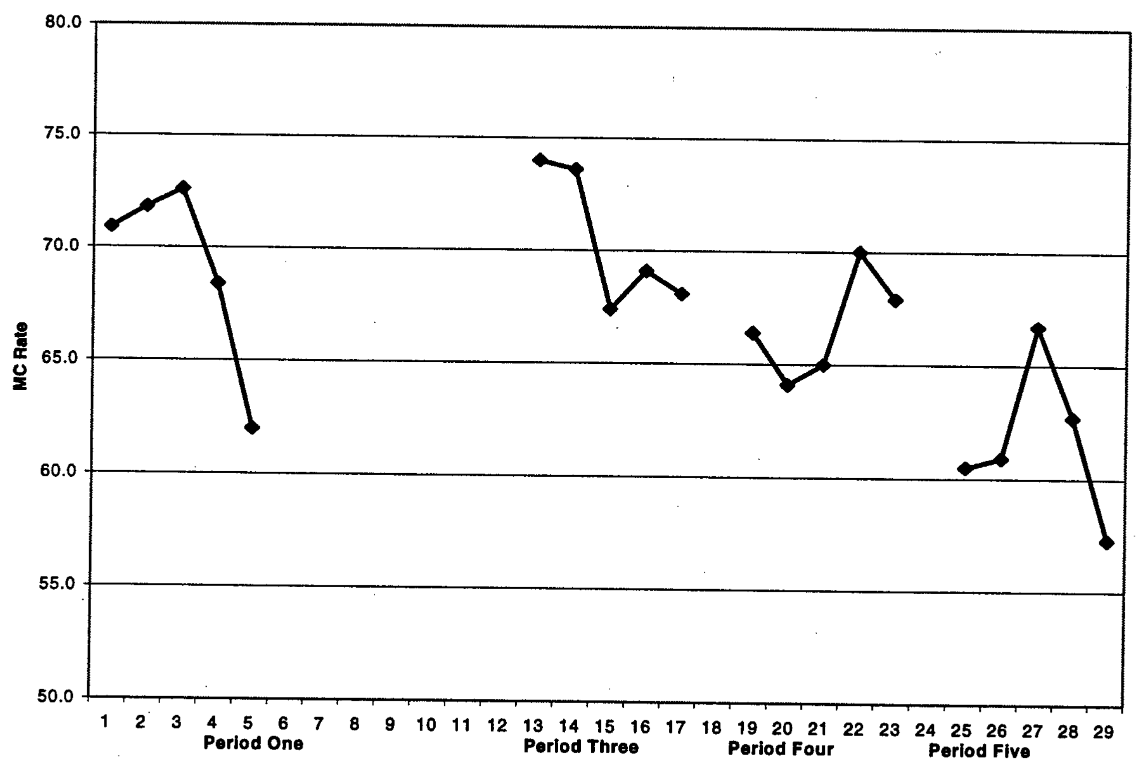

Figure 1. Mission Capable Rate Plots

Awaiting Maintenance. Awaiting Maintenance (AWM) was plotted for trend analysis. Again, all four periods of usable data are plotted and displayed in Figure 2. As stated earlier, Period Two is represented by the gap. The visual inspection method illustrates a downward sloping trend for the AWM variable. There is one outlier (data point 19) and according to Scott an investigation into this anomalous figure did not raise sufficient suspicion to remove the data point (1998:35).

As stated earlier, there is a statistical difference between Period One and Periods Three, and Five. Therefore, it is safe to conclude that the trend in the AWM Rate is downward sloping. Management prefers to see a downward sloping or stable trend for this indicator as this would show that the amount of maintenance waiting for resources is declining or stabilized.

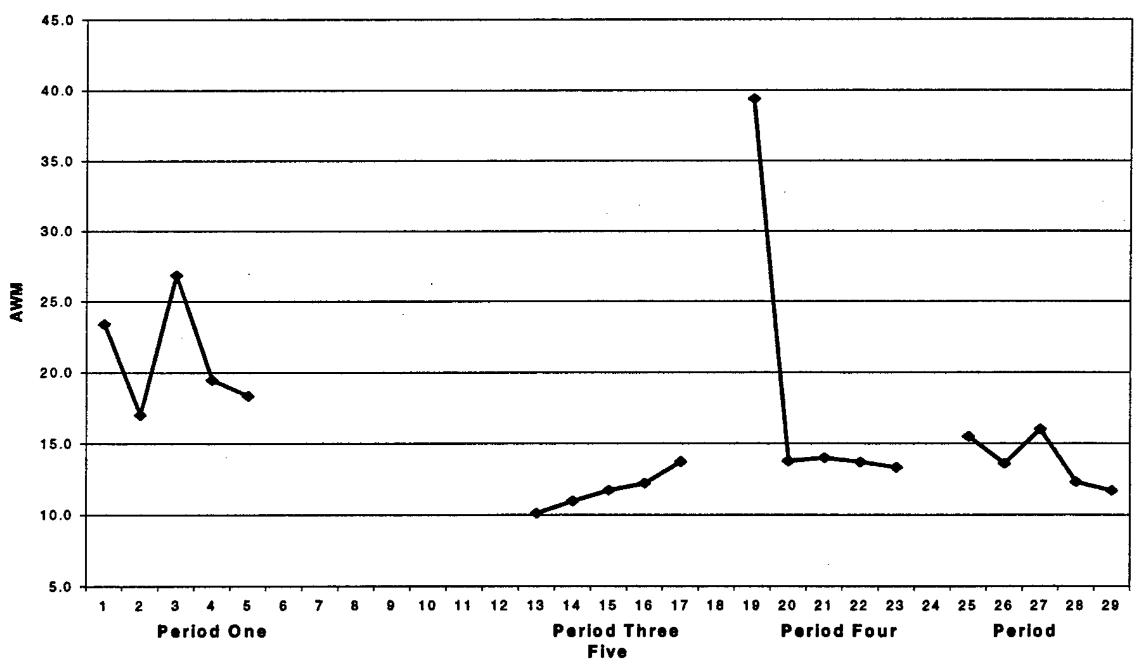

Figure 2. Awaiting Maintenance Trend Plots.

Home Station Reliability. Home Station Reliability was plotted for trend analysis. Again, all four periods of usable data are plotted and displayed in Figure 3. As stated earlier, Period Two is represented by the gap. The visual inspection method illustrates a trend for this variable that rises during the 12-hour shift period and remains up during Period Four.

As stated earlier, there is a statistical difference between Period Three and Periods One, and Five. Therefore, it is safe to conclude that the 12-Hour shift period has a positive impact on the variable trend. Management prefers to see a positive impact for this indicator as this would show that the workforce is meeting the flying schedule in a timely manner.

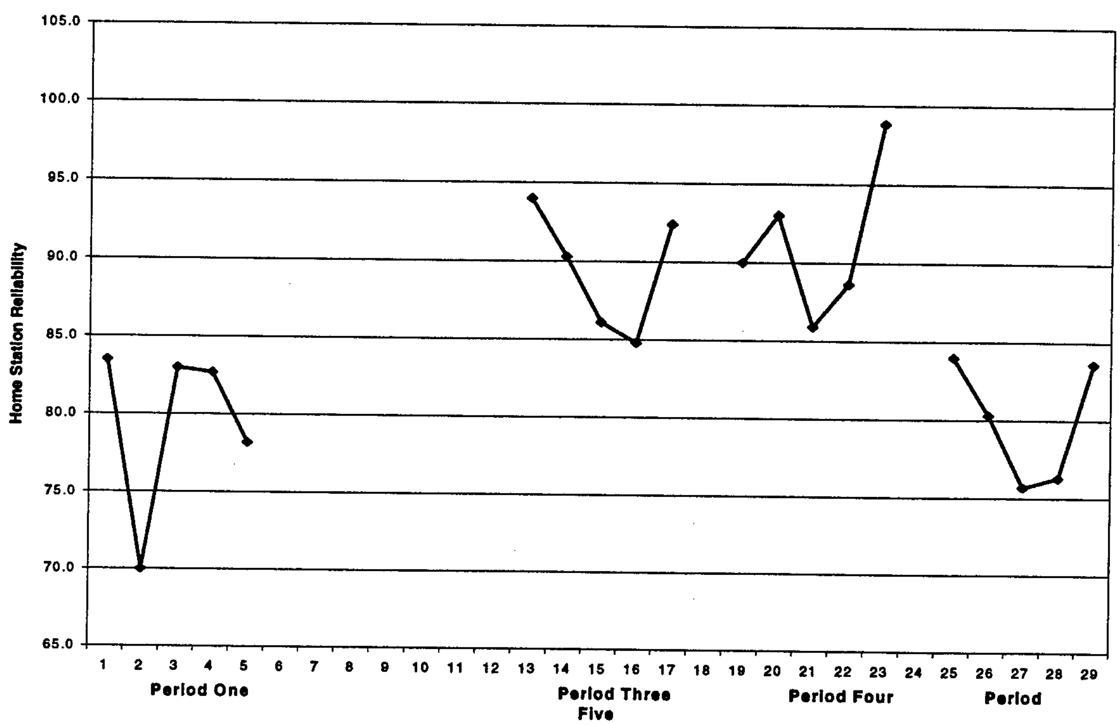

Figure 3. Home Station Reliability Trend Plots.

V. Recommendations and Conclusions

Summary of Findings

The data reveals interesting differences. Three of the five Logistics Readiness Indicators display statistical differences: MC Rate, Awaiting Maintenance, and Home Station Reliability.

The MC Rate, the outcome of interest, did not significantly change when the squadron changed from an 8-hour schedule to a 12-hour schedule, however, the MC Rate was lower during the final 8-hour schedule. For this indicator, an increase in the rate is desired and a slight increase is observed during the 12-hour shift period. The data collected does not reveal why the rate is lower as no other Logistics Readiness Indicator displays the same pattern of change in the mean. However, the manning level, one of the concomitant variables with significant differences, could have an impact on the MC Rate as the manning level shows a steady decline over the three-year period.

The Awaiting Maintenance Rate (AWM) significantly dropped when the squadron entered the 12-hour shift period and the unit was able to maintain this lower rate throughout the final 8-hour shift period. This drop in AWM is anticipated during the 12-hour shift period if the back load of work is maintenance related and not related to the unit waiting for parts. For this indicator, a decrease in the rate is desired and this is observed in the data. The final 8-hour shift period is not significantly different from the 12-hour period and this could be due to the unit doing an excellent job managing the resources required to keep the indicator low.

The Home Station Reliability was the only variable displaying a significant difference between the 8-hour periods and the 12-hour period. During the 12-hour period the reliability was 12 percent higher than the 8-hour shift periods. This rise is expected, as it is easier for the workforce to prepare the aircraft for the flying schedule during the 12-hour shift period. It appears that the 12-hour shift period had the most significant impact on this indicator. For this indicator, an increase in the rate is desired, and this is displayed during the 12-hour shift period.

The other two indicators, Labor Hours per Flying Hours and 12-Hour Fix Rate were not statistically different; however, there are some trends worth discussing.

Labor Hours per Flying Hour climbed slightly during the 12-hour shift period and dropped to its lowest mean during the final 8-hour shift period. For this indicator, a decrease in the rate is desired. This is not displayed in the data collected indicating the workforce was performing inefficiently during the 12-hour shift period.

The 12-Hour Fix Rate mean dropped to its lowest point during the 12-hour shift period and this is not an anticipated result. For this indicator, an increase in the rate is desired, however, this is not supported by the collected data. The mean is the highest during the final 8-hour shift period, indicating that the workforce may be performing more efficiently during the last year of data collection.

Research Questions

In order to bring the thesis full circle, it is important to restate the research questions and hypotheses, then, based on the research, answer them.

Question 1. Does the implementation of a fixed 12-hour shift routine (period 3) produce mission capable rate results that are higher than the 8-hour shift routines (periods 1, 4, and 5) and then degrade after suspected onset of worker fatigue?

In order to answer the first research question, hypothesis number one is restated.

H_0: 12-Hour shifts will not result in an increase in MC Rate.

H_a: 12-Hour shifts will result in an increase in MC Rate.

Answer 1. The statistical analysis reveals that Period 1 is not significantly different from Period 3, we fail to reject H_0 and conclude that 12-hour shifts do not result in an increase in MC Rate. However, the implementation of 12-hour shifts did produce two monthly means higher than any other 8-hour shift period data point and the mean for the five months of 12-hour shift period data was also higher than all the 8-hour shift period data means. Additionally, as the 12-hour shift period entered the third through fifth month of data collection the monthly mean drops approximately 10 percent and does not recover. This drop could be attributed to worker fatigue or other maintenance related issues. As worker fatigue is indirectly measured through the Logistics Readiness Indicators data and this data is inconclusive, it would be incorrect to correlate these two concepts.

Question 2. Does the average mission capable rate of the 12-hour shift routine (period 3) exceed the average mission capable rates of the 8-hour shift routines (periods 1,4, and 5).

In order to address the second research objective, hypothesis number two is restated.

H_0: 12-Hour shifts do not result in MC Rates that are higher than the 8-Hour shift periods.

H_a: 12-Hour shifts do result in MC Rates that are higher than the 8-Hour shift periods.

Answer 2. The quantitative analysis reveals that the 12-hour shift period (Period 3) does have MC Rate data points that are significantly higher than Period 5. Additionally the mean for the 12-hour shift period is higher than Period 5. Therefore, we reject H_0 and accept H_a as the acceptable hypothesis and conclude 12-hour shifts do result in MC Rates that are higher than the 8-hour shift periods.

Further quantitative analysis reveals the average mission capable rate of the 12-hour shift period exceeds the 8-hour period; however, the only statistically significant difference is between periods 3 and 5. There is no statistical difference between the Period 1 (the first 8-hour period) and Period 3 (the 12-hour period) nor Period 4 (the second 8-hour period). This result is interesting because we would expect the MC Rate to be significantly different between Period 1 and Period 3 when the workforce enters the 12-hour shift period. It is possible that the 12-hour shift period was implemented to hold the rate at a constant level. If the 12-hour period was not implemented it is possible for the MC Rate to significantly drop during Period 3.

Conclusions

Of the five performance variables, only two variables were influenced positively by the 12-hour shift period. So it is safe to conclude that the 12-hour shift period had a moderate positive impact on the performance variables. Management of these types of

organizations should use caution when implementing a long-term (more than a month) 12-hour shift period as the statistical analysis of the collected data does not support the long-term mission accomplishment.

Limitations

Each data point represents the average of 30 days of data, data is collected for five months, and there are only five data points per year. As the data is spread over five years, of which four years are valid samples, there are only 20 data points per variable. The overall sample size of twenty variables approaches the minimum number of data points required to get a normal distribution but is not enough to earn the normal distribution distinction as 30 data points are needed. As such, this study suffers from *near micronumerosity*, which arises when the number of observations barely exceeds the number of parameters to be estimated (Gujarati, 1995:326).

This study is done on a large aircraft maintenance unit located at Dover AFB, Delaware. As the data is collected on a military unit, it is difficult to control for history, maturation, and experiment mortality (Shane, 1998). As such, finding a period of time where "all other things remain the same" is a very difficult thing to do. Additionally, in an aircraft maintenance environment, there is a lot of 'noise' impacting the Logistics Readiness Indicators. The unit could have done everything necessary to repair an aircraft, and the aircraft will break again for a reason unrelated to the repair action. Additionally, the study was conducted during the October through February time periods and the results may be different during the summer months, as maintenance is easier to accomplish during the warmer months or during longer daylight periods. Additionally,

summer months may have greater variance in the manpower variable from deployments, leave, and permanent change of station assignments.

Suggestions for Further Research

The data collected fails to reveal why the MC Rate displays a downward sloping trend. After discussing this issue with my classmate Captain Greg Hutson, who wrote a thesis on issues on the Air Force Supply arena, he observed the decreasing trend in MC Rate seems to be in line with the trends of current USAF Total Not Mission Capable for Supply (TNMCS) rates. Although his area of focus was on fighter aircraft, cargo aircraft may follow a similar trend. It is feasible for the TNMCS rate to adversely impact the MC Rate of this study. As this thesis did not look at data from the supply arena, this is a potential research topic.

Another potential research topic could be a study on the aging aircraft issue. As we enter FY00, the mean age of the C-5 aircraft is 20 years. As aircraft age, they develop different problems and require different repairs such as rewiring or replacing fatigued metal from skin corrosion or bulkhead cracks. If the aircraft system fails more frequently or takes longer to repair, aircraft remain out of commission longer for maintenance reasons, adversely impacting the MC Rate and other productivity indicators.

One final research suggestion is a study involving the long-term effects of 12-hour shifts. Some of the short-term trend analysis indicates that the long-term effects could be negative, however this needs to be analyzed further.

Appendix A: Concomitant Variable Data

Month	Period	Sorties	Hours Flown	Manpower	Direct Labor Hours	Workforce Skill Level
Oct-94	1	729	3,018	945	42,280	64.02%
Nov-94	1	487	1,891	934	43,044	63.60%
Dec-94	1	509	1,852	921	36,268	63.08%
Jan-95	1	476	1,752	938	45,245	67.16%
Feb-95	1	407	1,511	937	44,842	66.92%
Oct-96	3	527	2,142	702	40,977	76.21%
Nov-96	3	426	1,992	712	38,780	75.28%
Dec-96	3	388	1,654	712	35,985	75.28%
Jan-97	3	382	1,557	710	41,190	75.07%
Feb-97	3	371	1,641	709	53,027	75.04%
Oct-97	4	524	2,397	699	33,333	72.53%
Nov-97	4	463	2,025	679	25,477	72.46%
Dec-97	4	348	1,472	676	25,667	72.04%
Jan-98	4	377	1,475	656	28,532	71.19%
Feb-98	4	499	2,813	641	28,634	70.83%
Oct-98	5	505	2,174	680	33,899	63.85%
Nov-98	5	351	1,340	680	28,247	64.00%
Dec-98	5	356	1,489	682	32,191	63.24%
Jan-99	5	328	1,493	691	31,439	63.63%
Feb-99	5	314	2,091	680	28,997	63.36%

Appendix B: Logistics Readiness Indicator Data

Month	Period	Avg AWM	MC Rate	HS Reliability	12 Hr Fix Rate	LbrHrPerFlyHr
Oct-94	1	23.4	70.9	83.5	46.7	14.0
Nov-94	1	17.0	71.8	70.0	39.1	22.8
Dec-94	1	26.9	72.6	83.0	72.7	19.6
Jan-95	1	19.5	68.4	82.7	55.6	25.8
Feb-95	1	18.4	62.0	78.2	69.2	29.7
Oct-96	3	10.1	74.0	94.0	61.1	19.1
Nov-96	3	11.0	73.6	90.3	37.2	19.5
Dec-96	3	11.7	67.4	86.1	60.7	21.8
Jan-97	3	12.2	69.1	84.8	58.2	26.5
Feb-97	3	13.7	68.1	92.4	50.8	32.3
Oct-97	4	39.4	66.4	90.0	58.1	13.9
Nov-97	4	13.8	64.1	93.0	58.1	12.6
Dec-97	4	14.0	65.0	85.9	62.2	17.4
Jan-98	4	13.7	70.0	88.6	69.0	19.4
Feb-98	4	13.3	67.9	98.8	65.8	10.2
Oct-98	5	15.5	60.5	84.0	79.4	15.6
Nov-98	5	13.6	60.9	80.3	69.8	21.1
Dec-98	5	16.0	66.7	75.7	61.5	21.6
Jan-99	5	12.3	62.7	76.3	55.6	21.1
Feb-99	5	11.7	57.3	83.6	60.5	13.9

References

Air Mobility Command. Unit Health of the Forces Reports and Maintenance Analysis Guide. AMC Pamphlet 21-102. Scott AFB: HQ AMC, 15 January 1997.

Akerstedt, T. "Work Hours and Continuous Monitoring of Sleepiness," Sleep Arousal and Performance. Eds, R. Broughton and R. Ogilvie. Boston MA: Birkhauser, 1992.

Alluisi, E and B. Morgan. "Temporal Factors in Human Performance and Productivity," in Human Performance and Productivity: Stress and Performance Effectiveness. Hillsdale NJ: Lawrence Erlbaum Associates, 1982.

Baker, T. and D. Morrisseau. "Performance and Alertness on 8 hour vs. 12 hour Shifts," in Conference on Human Factors and Power Plants. 117-120. Ed. E. Hagen. New York: Institute of Electrical and Electronic Engineers, 1992.

Budnick, L. D., D. E. Lerman, T. L. Baker, H. Jones, and C. A. Czeisler., "Sleep and Alertness in a 12-Hour Rotating Shiftwork Environment," Journal of Occupational Medicine, 3:1295-1300 (1994).

Campbell, C. Effects of Shiftwork on Air Force Aircraft Maintenance Personnel. MS Thesis, AFIT/GTM/LAL/98S-2. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1998.

Campbell, D. and J. Stanley. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally College Publishing Company, 1963.

Cooper, D. and W. Emory. Business Research Methods. Chicago: Richard D. Irwin Inc. 1995.

Department of the Air Force. Equipment Inventory, Status, and Utilization Reporting. AFI 21-103. Washington: HQ USAF, 1 September 1997

Duchon, J. and T. Smith. "Extended Workdays and Safety," International Journal of Industrial Ergonomics, 11: 37-49 (1993).

Ferrer, C. "Circadian Rhythm Desyncronosis in Military Deployments: A Review of Current Strategies," Aviation, Space, and Environmental Medicine, 66: 571-578. (June 1995).

Folkard, S. and T. Monk. "Shiftwork and Performance," Human Factors, 21: 483-492 (1979).

Gordon, N. "The Prevalence and Health Impact of Shiftwork," American Journal of Public Health, 76: 1225-1228 (1986).

Graeber, R. "Aircrew Fatigue and Circadian Rhythmicity," Human Factors in Aviation. Eds. E. Wiener and D. Nagel. San Diego: Academic Press, 1988.

Gujarati, D. N. Basic Econometrics (3rd ed). New York: McGraw-Hill, 1995.

Harma, M. "Individual Differences in Tolerance to Shiftwork: A Review," Ergonomics, 36: 101-109 (1993).

Haslam, D. "Sleep Loss, Recovery Sleep, and Military Performance," Ergonomics, 36: 101-109 (1993).

Kachigan, S. Statistical Analysis. New York: Radius Press co, 1986.

Klein, M. "Technical Comparison of 8- vs. 12-Hour Shift Schedules: A Case Study," Proceedings of the Human Factors Society 32nd Annual Meeting. 767-771. Santa Monica CA: Human Factors Society, 1988.

La Dou, J. "Health Effects of Shiftwork," Western Journal of Medicine, 137: 525-530 (1982).

Lewis, P. and D. Swaim. "Evaluation of a 12 Hour Day/Shift Schedule," Proceedings of the Human Factors Society 30th Annual Meeting. 885-889. Santa Monica CA: Human Factors Society, 1986.

Liou, T and M. Wang. "Rotating-Shift System vs. Fixed-Shift System," International Journal of Industrial Ergonomics 7: 63-70 (1991).

Maddox, M. "Human Factors Guide for Aviation Maintenance." Excerpt from book, n. page. http://www.hfskyway.com/document.htm. August 1999.

McClave, J., P Benson, and T. Sincich. Statistics for Business and Economics. Upper Saddle River NJ: Prentice Hall, 1998.

Miller, D. and A. Swain. "Human Error and Human Reliability," Handbook of Human Factors. Ed. G. Salvendy. New York: John Wiley and Sons, 1987.

Monk, T. "Human Factors Implications of Shiftwork," International Reviews of Ergonomics: Current Trends in Human Factors Research and Practice. London: Taylor and Francis, (1989).

Monk, T., S. Folkhard and A. Wedderburn. "Maintaining Safety and High Performance on Shiftwork," Applied Ergonomics, 27: 17-23 (1996).

Neter, H., W. Wasserman, and M. Kutner. Applied Linear Statistical Models. Chicago: Richard D. Irwin, Inc, 1990.

Nicholson, A. N., and B. M. Stone. "Sleep and wakefulness handbook for flight medical officers" (AGARD-AG-270E). Neuily-Sur-Seine, France: Advisory Group for Aerospace Research and Development (AD-A115 076). 1982.

Office of Technology Assessment Biological rhythms: Implications for the worker (OTA-BA-463). Washington DC: US Government Printing Office. (1991).

Overland, D. Comparison of Effects of Change from 8 to 12 Hour Shifts on Air Force Aircraft Maintenance Workers. MS Thesis, AFIT/GTM/LAL/97S-8. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1997.

Palmer, B. et al. Scientific Review of Air Mobility Command Crew Rest Policy and Fatigue Issues: Volume I: Final Report (CSERIAC-RA-96-007A-VOL 1). Wright-Patterson AFB OH: Crew Systems Ergonomics Information Analysis Center, 1996 (AD-B218 332).

Pierce, J. L. and R. B. Dunham. "The 12-hour work day: A 48-hour, eight-day week." Academy of Management Journal, 35(5) 1086-1098. (1992).

Pritchand, R. et al. "The Evaluation of an Integrated Approach to Measuring Organizational Productivity," Personal Psychology, 42: 69-115 (1989).

Reynolds, Daniel. Instructor, Air Force Institute of Technology, Dayton OH. Personal Interview. 24 May, 1999.

Rosa, R. R., M. J. Colligan, and P. J. Lewis. "Extended workdays: Effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables." Work and Stress, 3, 21-32. (1989).

Rosa, R. R. Performance, Alertness, and sleep after 3.5 years of 12-Hour shifts: a follow-up study. Work and Stress, 5(2), 107-116. (1991).

Rosekind, M. "NASA Ames Fatigue Countermeasures Program," FAA Aviation Safety Journal, 3: 20-25 (1993).

Scott, K. A Comparison of 8-Hour vs.12-Hour Shifts on Performance, Health, and Safety in a USAF Aircraft Maintenance Squadron. MS Thesis, AFIT/GLM/LAL/98S-11. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1998.

Shane, G. Internal Validity. Class presentation for research methods, Air Force Institute of Technology, Wright-Patterson AFB, OH. November 1998.

Williamson, A. M., C. G. I. Gower, and B. C. Clarke. "Changing the hours of shiftwork: A comparison of 8- and 12-hour shift rosters in a group of computer operators." Ergonomics. 37(2) 287-298. (1994).

Vita

Captain David P. Collette is from Merrimack, New Hampshire. He enlisted in the United States Air Force in 1987 serving as a Avionics Journeyman on F-111 and F-15 Aircraft at Eglin Air Force Base, Florida. Captain Collette graduated from the Community College of the Air Force with an Associate of Science Degree in Applied Avionics Technology. Captain Collette also graduated from Embry-Riddle Aeronautical University, College of Continuing Education, at Eglin Air Force Base Florida in 1994 with a Bachelor of Science Degree in Professional Aeronautics and a Minor in Safety. He received his commission from Officer Training School in 1995.

After completing the Aircraft Maintenance/Munitions Officer Course at Sheppard Air Force Base, Texas, as a Distinguished Graduate, Captain Collette was assigned to the 56th Fighter Wing at Luke Air Force Base, Arizona. There he served two years in the 56th Equipment Maintenance Squadron, the first year as the Munitions Flight Commander and the second year as the Fabrication Flight Commander. His last year in Arizona he served as the Sortie Support Flight Commander in the 21st Fighter Squadron. Following the 21st Fighter Squadron, Captain Collette entered the Air Force Institute of Technology at Wright-Patterson AFB, Ohio. He graduated in 1999 with a Masters degree in Logistics Management. Captain Collette was reassigned as an instructor at the Air Force Institute of Technology School of Systems and Logistics. Captain Collette and his wife Arlene have been married for 4 years. They have one daughter – Lindsay, age 10.

Permanent Address: 11 Sunset Drive
Merrimack, NH 03054-4201

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1999	Master's Thesis

4. TITLE AND SUBTITLE
COMPARISON OF THE EFFECTS OF EIGHT-HOUR AND TWELVE-HOUR SHIFTS ON AIR FORCE AIRCRAFT MAINTENANCE PRODUCTION LEVELS

5. FUNDING NUMBERS

6. AUTHOR(S)

David P. Collette, Captain, USAF

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
2950 P Street
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GLM/LAL/99-S4

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Robert Hamm, Lieutenant Colonel, USAF
Commander
436 Aircraft Generation Squadron
Dover AFB, Delaware 19902-5710

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 Words*)

This is a follow-on study that examined the effects of converting a large aircraft maintenance squadron from 8-hour shifts to 12-hour shifts. The squadron studied converted its 24-hour maintenance work force from three 8-hour work shifts to two 12-hour work shifts. Data was collected from four different time periods. Three time periods were used for a primary analysis and all four time periods were used for trend analysis. To determine if the 12-hour work shift was effective, workforce productivity was measured during the different work shift periods. Results showed an increase in two productivity measurements, no-change in two productivity measurements, and a decrease in one productivity measurement. It was concluded that 12-hour shifts have a moderate impact on productivity measurements.

14. Subject Terms
Productivity, 12-hour shifts, 8-hour shifts, shiftwork, fixed shifts, rotating shifts, compressed shifts, aircraft maintenance, performance, Dover AFB

15. NUMBER OF PAGES
59

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
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